

# Summary of WG3 Discussions

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# WG3 Benchmark “Prioritization”

- The list of of available benchmark models in WG3 is quite extensive, for example:

<https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCHXSWG3Benchmarks2HDM>

<https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCHXSWGGM>

<https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCHXSWG3BenchmarksNon2HDM>

<https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCHXSWGMSMNeutral#Available%20benchmark%20scenarios>

<https://arxiv.org/abs/1808.07542>

<https://twiki.cern.ch/twiki/bin/view/LHCPhysics/NMSSMBenchmarkPoints>

<https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCHXSWGExoticDecay#Benchmark%20models>

<https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCHXSWG3Flavorful2HDM>

# WG3 Benchmark “Prioritization”

- The experiments are already searching for many of these signatures, however there are also many that are not yet covered.
- Unfortunately its not easy to initiate so many brand new analysis efforts within the experiments.
- Of course we should aim for full coverage of all possible signatures, but person power is a finite resource and an analysis takes a significant amount of time.
- So the proposal for discussion is to hear people's opinions on the (partly hypothetical) questions:
  - If we could initiate only one new analysis effort in the experiments, which one do you think it should be and why?
  - What are the experimental challenges for that search? Did we trigger on it already or not?

# Double Higgs Searches

- [Extended Scalars Group](#): Broaden the reach of existing searches

WG3 Extended Scalars - top priority benchmark

$H_3 \rightarrow H_1 H_2$ , where all three Higgs bosons have different masses.  
 $h_{125}$  could be any of these three.

Neighbouring searches:

$h_{125} \rightarrow aa$ , assuming the two  $a$ 's have the same mass

→ instead consider  $h_{125} \rightarrow a_1 a_2$

$X \rightarrow h_{125} h_{125}$  ( $X = \text{scalar}$ )

$X \rightarrow aa \rightarrow 4\gamma$  and  $X \rightarrow SS \rightarrow 4W$  (ATLAS)

→ instead consider  $X \rightarrow h_{125} S$  (or  $X \rightarrow h_{125} a$ )

Models in which this appears:

- 2HDM with explicit CP violation (C2HDM)

3 mixed-CP neutral scalars,  $H_1, H_2, H_3$  (one is 125 GeV)

- 2HDM + singlet (N2HDM)

3 CP-even neutral scalars  $H_1, H_2, H_3$  (one is 125 GeV)

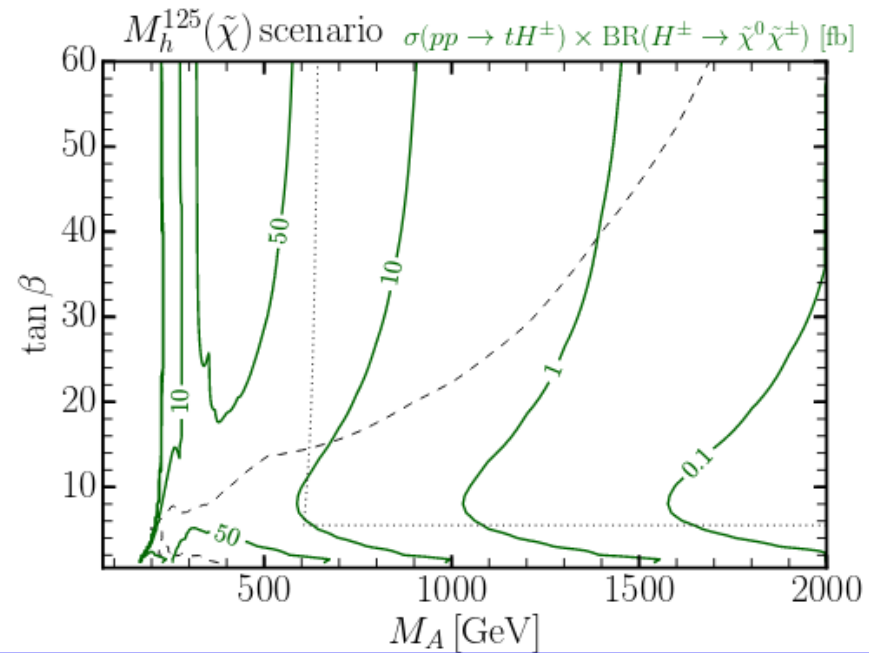
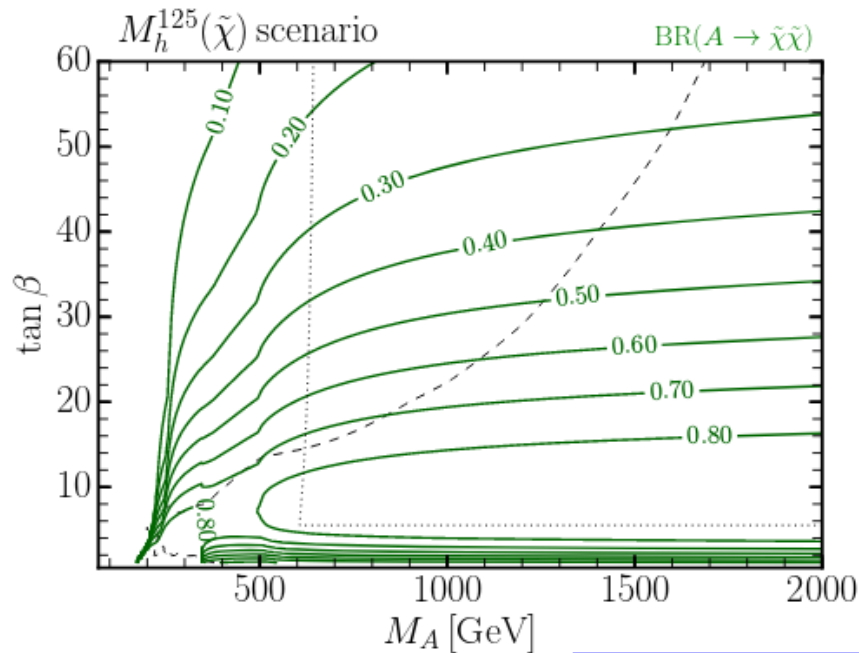
# BSM Higgs decays to EWKin

- [MSSM Subgroup](#): Decays to SUSY particles covers difficult phase space

The production through Higgs bosons can be the dominant production mode of  $\tilde{\chi}_i \tilde{\chi}_j$  or  $\tilde{\tau} \tilde{\tau}$ , larger than direct production. The resonant Higgs boson(s) yield(s) specific kinematics, not necessarily well captured by the existing searches.

Example: ✓  $M_h^{125}(\tilde{\chi})$  scenario: [1808.07542]

$M_1 = 160$  GeV,  $M_2 = \mu = 180$  GeV, Decay modes  $H/A/H^\pm \rightarrow \tilde{\chi}_i \tilde{\chi}_j$ :



scenarios, which set  $m_{\tilde{\chi}_3^0} = m_{\tilde{\chi}_2^0} = m_{\tilde{\chi}_1^0} + 100$  GeV, such that the dominant decay chain is  $H/A \rightarrow Z \tilde{\chi}_1^0 \tilde{\chi}_1^0$ . → Mono-Z searches.

- $WW \tilde{\chi}_1^0 \tilde{\chi}_1^0$  with 43%
- $WWZ \tilde{\chi}_1^0 \tilde{\chi}_1^0$  with 51% through an intermediate  $\tilde{\chi}_1^\pm$
- $WWW \tilde{\chi}_1^0 \tilde{\chi}_1^0$  with 6% through intermediate  $\tilde{\chi}_2^0$  and  $\tilde{\chi}_1^\pm$ .

# Inert 2HDM

- [Tania Robens, et. al.:](#)

**Did we miss BSM in already investigated final states ?**

- possible example: **Inert Doublet Model**
- 2HDM with  $Z_2$  symmetry, 4 additional scalars  $H, A, H^\pm$   
one of these: dark matter candidate (here: H)
- production modes:  $HA, HH^\pm, AH^\pm, H^+H^-$
- decays:  $A \rightarrow ZH, H^\pm \rightarrow W^\pm H$
- final state: **electroweak gauge boson(s) and MET**
- cross sections:  
**up to 1 pb at LHC13** (HA production for  $m_H \sim 60$  GeV)

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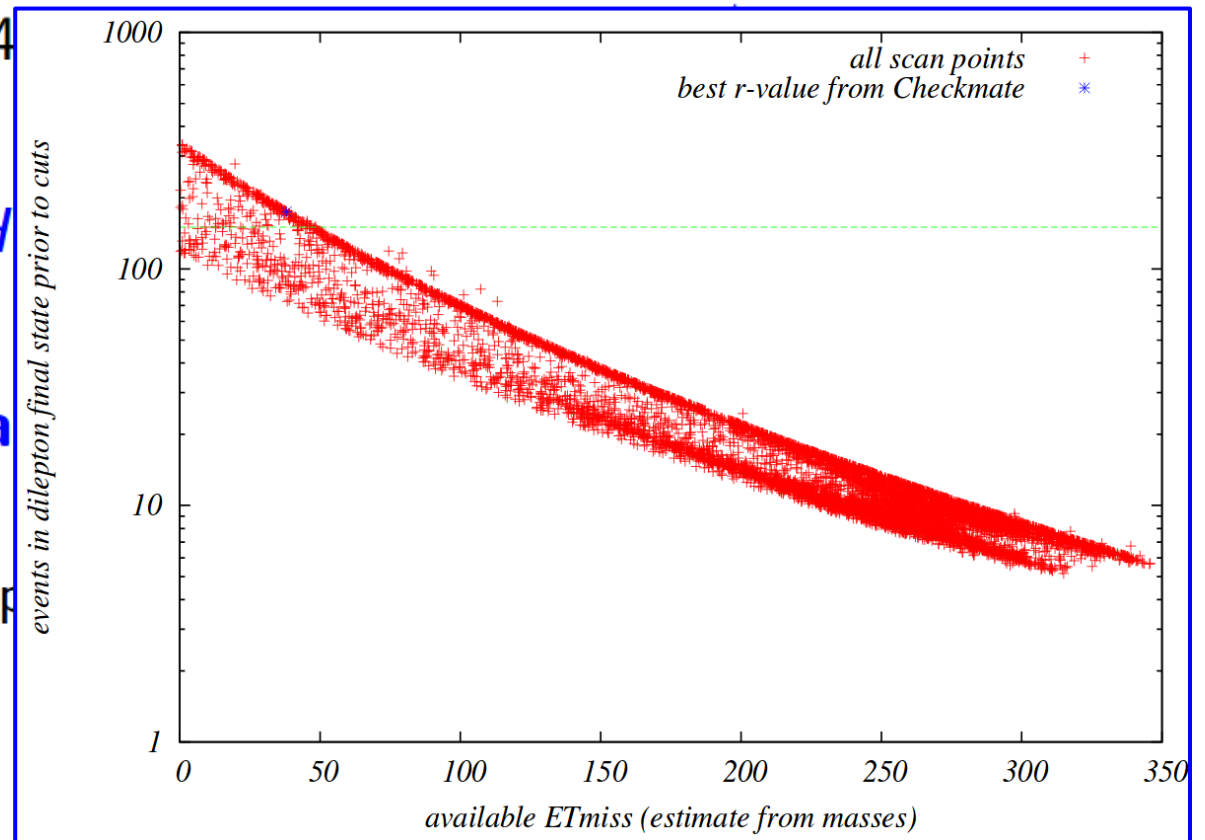
- production modes:  $HA, HH$

- decays:  $A \rightarrow ZH, H^\pm \rightarrow$

- final state: **electroweak ga**

- cross sections:

**up to 1 pb at LHC13** ( $HA$  p



# Charged Higgs Searches

- [Adil Jueid, et. al.](#) :  $H^+ \rightarrow tb$  is a high priority search, make it more sensitive by including top quark polarization observables
  - We start by remarking that  $tH^- + c.c$  depends on  $g_{tbH^+}$  (in addition to the charged Higgs boson mass)

$$g_{tbH^+} = i(C_L P_L + C_R P_R), \quad C_L = \frac{1}{\sqrt{2}v} m_t \kappa_u^A, \quad C_R = \frac{1}{\sqrt{2}v} m_b \kappa_d^A.$$

$$\kappa_u^A = 1 / \tan \beta \quad \text{for all the Yukawa type of 2HDM and}$$
$$\kappa_d^A = \tan \beta (-1 / \tan \beta) \quad \text{for type-II and type-Y (type-I and type-X)}$$

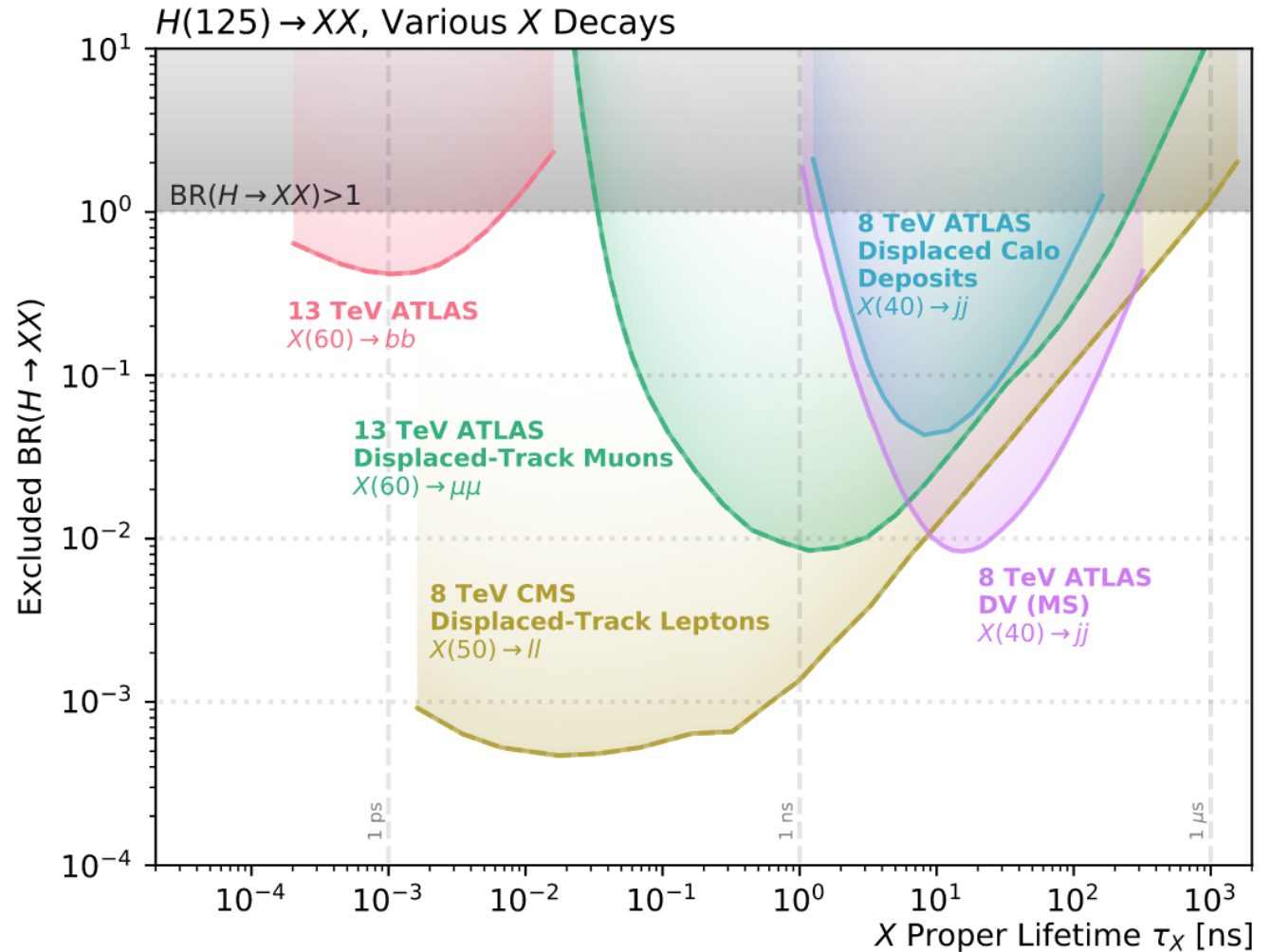
What are the implications of this?

- In type-I (type-X), this coupling is always left-handed (with very small contribution from right-handed component)  $\implies$  **top quark is produced with negative polarisation in the helicity basis.**
- In type-II (type-Y),  $g_{tbH^+}$  can be L- dominated, R- dominated or purely scalar  $\implies$  **Top quark polarization is arbitrary and it's only controlled by  $\tan \beta$  (in addition to charged Higgs boson mass.**



# Higgs Decays to LLP

- Well motivated by many BSM models
- “Target” BR is  $10^{-4}$  in all possible final states
- Lack of results currently in hadronic final states for intermediate lifetimes
- Is there something we can do in WG3 to stimulate more interest amongst experimentalists?



# Summary of the Summary

- Through a great effort, many new/updated benchmarks are available
- We are now trying to restart the discussions between theorists and experimentalists about which are the most promising channels for discovery
- We are thinking about if any new ideas could be promoted/served by WG3, e.g. Higgs to LLP